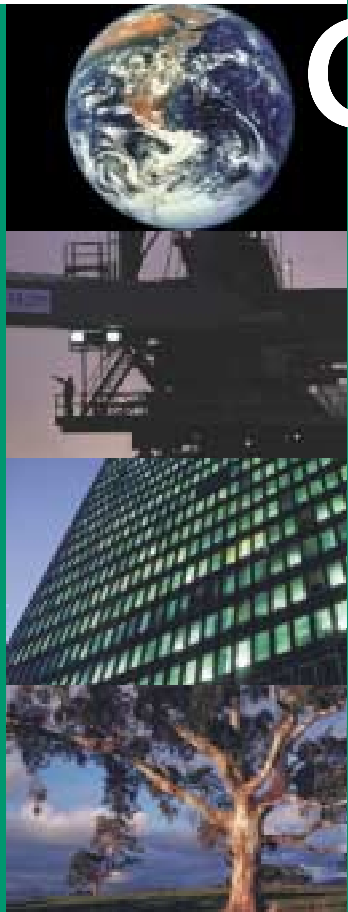
Victorian Greenhouse Strategy

understanding climate change



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For additional copies of this booklet or for more information on the Victorian Greenhouse Strategy, visit **www.greenhouse.vic.gov.au** or call the NRE Customer Service Centre on **136 186**.

Printed on Harvest using the waterless printing process. Harvest is made predominantly from bagasse fibre, a waste product from the sugar industry.

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Foreword

Climate change due to the enhanced greenhouse effect is one of the most important global environmental challenges confronting the world today.

The significance of this challenge is made clear in the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) which finds that:

> data for the past 1000 years suggests that warming over the past 100 years was unusual and unlikely to be natural in origin

> the 1990s was the warmest decade, and 1998 the warmest year, in the instrumental record since 1861

> there is new evidence that most warming over the last 50 years is attributable to human activities.

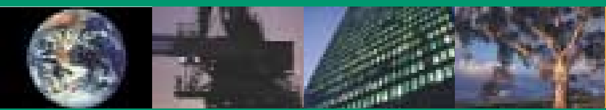
The Report indicates that globally averaged surface temperatures are projected to increase by 1.4 to 5.8 degrees Celsius from 1990 to 2100, and that sea levels are projected to rise by 0.09 to 0.88 metres over this period.

Given the environmental, economic, and health impacts that would result from such changes, it is important that countries around the world take steps to reduce greenhouse gas emissions in an effort to minimise the impacts of climate change. It also is important that we seek to improve our understanding of the nature of these potential impacts in order to develop sensible strategies for adapting to future climate change.

A prerequisite for effective action on these fronts is the building of knowledge and understanding within the community of the broad range of climate change issues. The Victorian Government regards climate change information and education programs as a key consideration for its Victorian Greenhouse Strategy.

This information booklet has been produced to assist in raising awareness and understanding of climate change issues throughout the community. Its distribution to secondary schools throughout the State will provide an important resource to increase understanding among the decision makers and leaders of tomorrow.

THE HONOURABLE CANDY BROAD, MLC
Minister for Energy and Resources



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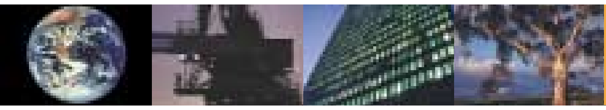
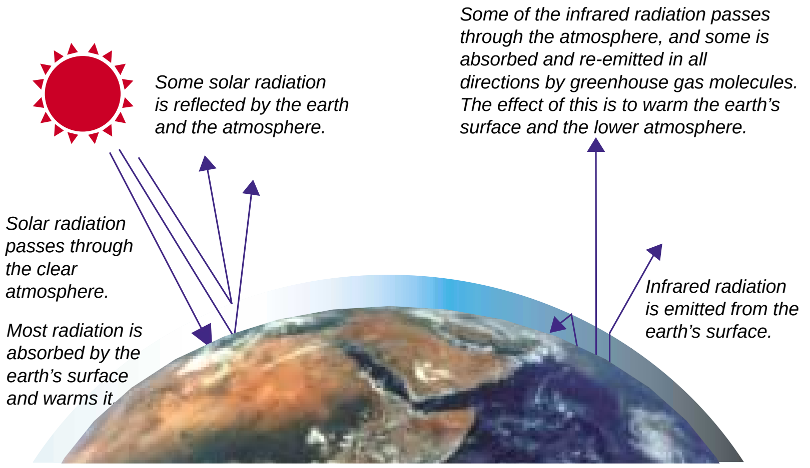


1 What is the green

The Earth's climate system is finely balanced. Increased temperatures in the lower atmosphere are likely to produce changes to weather and climate worldwide.

The Greenhouse Effect



Atmospheric heat trapping: Greenhouse gases in the atmosphere absorb some of the heat released by the Earth's surface, maintaining habitable temperatures in the lower atmosphere.

house effect?

The Earth's atmosphere stretches to more than 100 kilometres above our heads.

Nitrogen and oxygen make up about 99% of dry air. However, air also contains water vapour as well as small quantities of carbon dioxide, methane and other gases that have a special property – they trap heat. Water vapour, carbon dioxide and other heat-trapping gases are known as greenhouse gases.

The natural greenhouse effect

About half of the Sun's energy reaching the top of our atmosphere penetrates to the Earth's surface. The rest is either reflected back into space by the atmosphere or absorbed by gases and dust particles. The solar energy that does reach the Earth's surface warms the land and oceans. In turn, the land and oceans release heat in the form of infrared radiation.

Greenhouse gases absorb some of this radiation, warming the lower atmosphere. This absorption of heat, which keeps the surface of our planet warm enough to sustain us, is called the greenhouse effect. Without heat-trapping greenhouse gases in the air, the Earth's surface temperature would average a frigid –18°C, rather than 15°C.

Water vapour is responsible for about three-quarters of the natural greenhouse effect. The next most significant greenhouse gas is carbon dioxide.

Climate change

Higher concentrations of greenhouse gases in the Earth's atmosphere will lead to increased trapping of infrared radiation. This adds to the natural greenhouse effect, producing an *enhanced* greenhouse effect. The Earth's climate system is finely balanced. Increased temperatures in the lower atmosphere are likely to produce changes to weather and climate worldwide.

The enhanced greenhouse effect is often referred to as climate change or global warming.

In addition to generating greenhouse gases, human activity, especially in industrialised regions, is adding microscopic particles (aerosols) to the atmosphere. These aerosols have a localised cooling effect, which in some places may be partly masking global warming from the enhanced greenhouse effect.

The greenhouse effect and ozone depletion

The greenhouse effect and ozone depletion are separate environmental issues, although there are some linkages between the two.

The *greenhouse effect* refers to the ability of some gases, known as greenhouse gases, to trap heat within the atmosphere. Adding greenhouse gases to the atmosphere is likely to lead to global warming and climate change.

Ozone depletion refers to the destruction of the ozone layer, which is part of the atmosphere 20 to 30 kilometres above the ground. Ozone gas in this part of the atmosphere (the stratosphere) prevents harmful ultraviolet radiation from the sun reaching us. Exposure to this radiation can cause skin cancer, eye damage and other health problems.

The greenhouse effect and ozone depletion are both due to gases released into the atmosphere by humans. Chlorofluorocarbons (CFCs) are both greenhouse gases and ozone depletors.

The greenhouse effect may be worsening ozone depletion. The reason for this is that additional heat trapping in the lower atmosphere means that less heat reaches the stratosphere. The stratosphere becomes colder, accelerating ozone depletion.

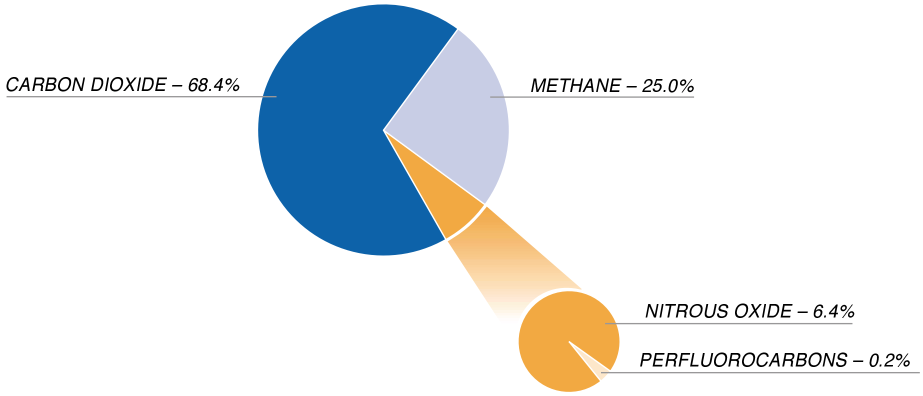
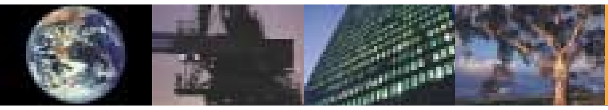


Figure 1: Relative contributions of greenhouse gases (in terms of CO_2-equivalent) to Australia's net national emissions. (1999 National Greenhouse Gas Inventory. www.greenhouse.gov.au/inventory)



2 What are the gree

The Kyoto Protocol to the United Nations Framework Convention on Climate Change is designed to commit industrialised nations to reducing emissions of six types of greenhouse gases.

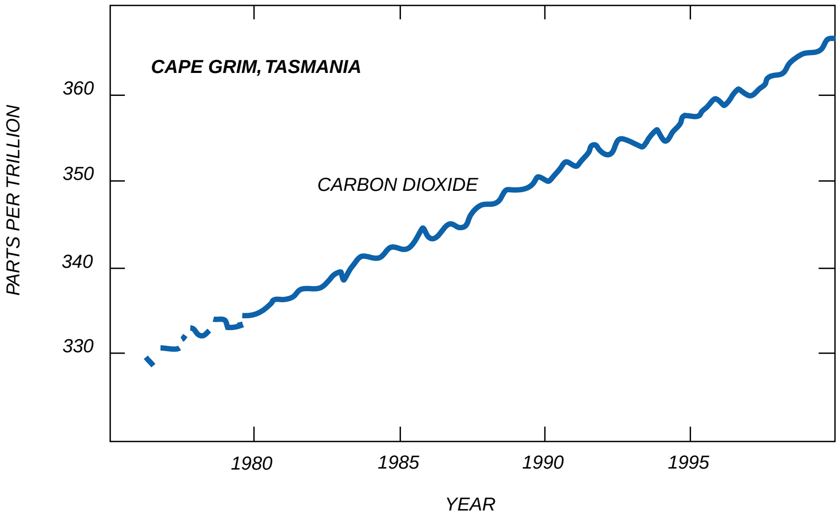


Figure 2: Atmospheric concentration of carbon dioxide as measured at Cape Grim in Tasmania. (CSIRO)

nhouse gases?

The atmosphere consists of a mixture of gases including nitrogen and oxygen. Also present are a number of 'greenhouse' gases that trap heat emitted by the ground and the oceans. These naturally occurring greenhouse gases, such as water vapour, carbon dioxide and methane keep the surface of our planet warm enough to sustain us. Without heat-trapping greenhouse gases the surface would have an average temperature of -18°C rather than our current average of 15°C.

However, human activity during the past 200 years has added to emissions of these greenhouse gases. We have also produced and released new chemicals such as Hydrofluorocarbons (HFCs) that are greenhouse gases.

Higher concentrations of greenhouse gases will lead to increased heat trapping, producing an enhanced greenhouse effect. The result is likely to be changing weather and climate.

The Kyoto Protocol to the United Nations Framework Convention on Climate Change is an international agreement designed to commit industrialised nations to reducing emissions of six types of greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Figure 1 presents the contribution made by various greenhouse gases to Australia's total emissions.

Carbon dioxide

Carbon dioxide is responsible for at least half of the enhanced greenhouse effect. The concentration of carbon dioxide in the atmosphere is growing at a rate of approximately 0.4% per year. Figure 2 shows changes to atmospheric concentrations of carbon dioxide in the southern hemisphere since the 1970s. Figure 3 shows a range of possible carbon dioxide concentrations during the next 100 years.

We add carbon dioxide to the atmosphere by burning fossil fuels (oil, natural gas and coal) to generate energy; by clearing land and burning vegetation; and through industrial processes such as the manufacturing of cement. Growing forests helps remove carbon dioxide from the atmosphere.

Methane

There is much less methane in the atmosphere than carbon dioxide, but it is a more powerful greenhouse gas. Methane contributes about 10 to 15 % of the enhanced greenhouse effect.

Methane forms when organic material decomposes in the absence of oxygen. Major sources of methane are ruminant animals such as cows and sheep, decomposition of animal wastes, rice paddies, landfills, termites, burning vegetation, coal mines and oil and gas fields. Most of the extra atmospheric methane in recent years has come from increased rice growing and cattle numbers.

Methane persists in the atmosphere for about 10 years.

Nitrous oxide

Major sources of nitrous oxide include motor vehicles, fertilisers, burning vegetation and industrial processes such as the production of chemicals. Nitrous oxide persists in the atmosphere for more than 100 years.

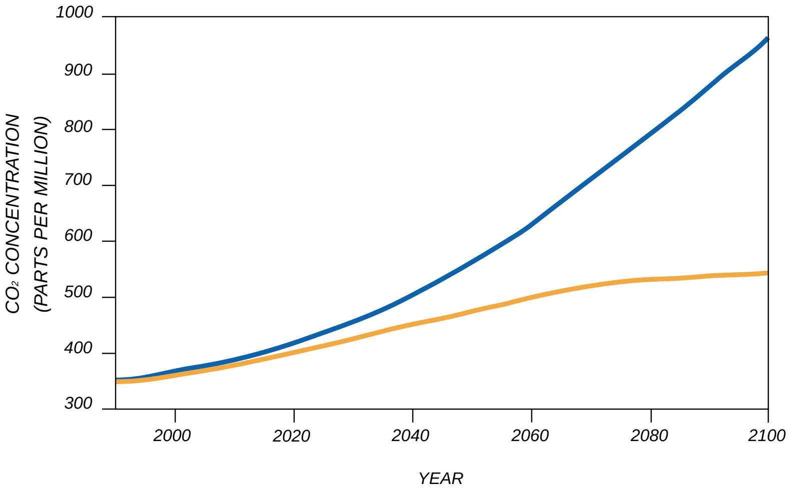


Figure 3: Range of projected future carbon dioxide concentrations in the atmosphere, depending on different scenarios for future trends in global greenhouse gas emissions. The two lines are the upper and lower projections as reported in the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (IPCC, 2000).

Hydrofluorocarbons (HFCs)

HFCs are CFCs with the chlorine removed. HFCs have been introduced as CFC replacements because they do not destroy the ozone layer. HFCs are used as refrigerants and in the plastics industry. They are potent greenhouse gases, and have a global warming impact 140 to 11,700 times greater than CO_2 (see Table 1).

Perfluorocarbons (PFCs)

Perfluorocarbons are by-products of aluminium smelting and are present in the atmosphere in very small concentrations. They are, however, very powerful greenhouse gases, partly because they have an atmospheric lifetime of thousands of years.

Sulfur hexafluoride

Sulfur hexafluoride is probably the most powerful greenhouse gas. It is used as an insulator in the electricity industry. One kilogram of sulfur hexafluoride can produce warming equivalent to the release of almost 24 tonnes of carbon dioxide!

Other important gases

There are several other gases in the atmosphere that, although not themselves greenhouse gases, influence climate.

The hydroxyl radical is a highly reactive gas that helps the atmosphere cleanse itself of pollutants. The hydroxyl radical reacts with methane, eventually removing it from the atmosphere. This is the main way in which atmospheric methane gas is destroyed.

The hydroxyl radical also reacts with carbon monoxide. If concentrations of carbon monoxide increase in the atmosphere, there would be fewer hydroxyl radicals. As a result, methane molecules would last longer in the atmosphere. In this way, carbon monoxide can have an indirect effect on climate, even though it is not itself a greenhouse gas.

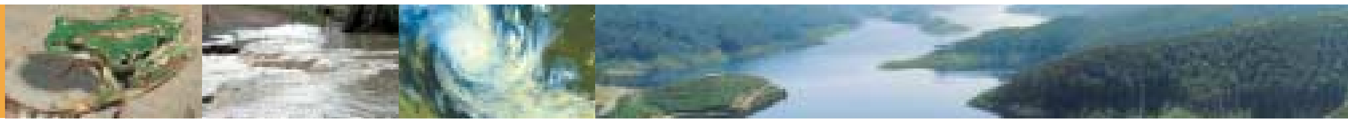
Carbon monoxide, hydrocarbons and oxides of nitrogen can react to form ozone in the lower atmosphere. Ozone is a greenhouse gas. Ozone concentrations in the lower atmosphere are higher than in pre-industrial times, especially in the northern hemisphere.

Global warming potentials

Each greenhouse gas has different physical properties and a different potential to trap heat. Scientists have calculated a *global warming potential* for each greenhouse gas, based on factors such as the extent to which they absorb heat and their atmospheric lifetime. Global warming potentials (see Table 1) allow the warming effect of different greenhouse gases to be compared.

For example, methane has a global warming potential 21 times greater than CO_2. If emissions of carbon dioxide were 100 tonnes and methane emissions were 1 tonne, total CO_2-equivalent emissions would be 121 tonnes – that is, (100 x 1) + (1 x 21).

Table 1 also shows the concentration of various greenhouse gases in pre-industrial times and today (1999).



Gas	Concentration		Increase from pre-industrial to 1999*	Global warming potential compared with CO_2 **
	Pre-industrial	1999		
Carbon dioxide	~280 ppmv	367ppmv	31%	1
Methane	~700 ppbv	1700 ppbv	143%	21
Nitrous oxide	~275 ppbv	315 ppbv	15%	310
Hydrofluorocarbons	0	20 pptv		140–11,700
Sulfur hexafluoride	0	5 pptv		23,900
Perfluorocarbons	40 pptv	80 pptv	100%	6,500–9,200

ppmv = parts per million by volume; ppbv = parts per billion by volume; pptv = parts per trillion by volume.

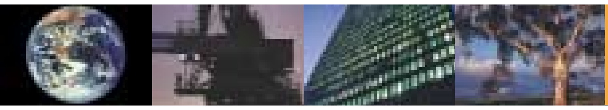
* *A percentage increase cannot be shown for synthetic gases that did not exist in pre-industrial times.*

** *Calculated over a 100 year time horizon*

Global warming potentials are expressed as a multiple of the global warming potential of carbon dioxide.

Source: Intergovernmental Panel on Climate Change

Table 1: Concentrations of greenhouse gases, pre-industrial and 1999



3 Greenhouse sinks

Greenhouse gases released from a source such as the burning of fossil fuels do not stay in the atmosphere forever. They are removed from the atmosphere by greenhouse sinks.

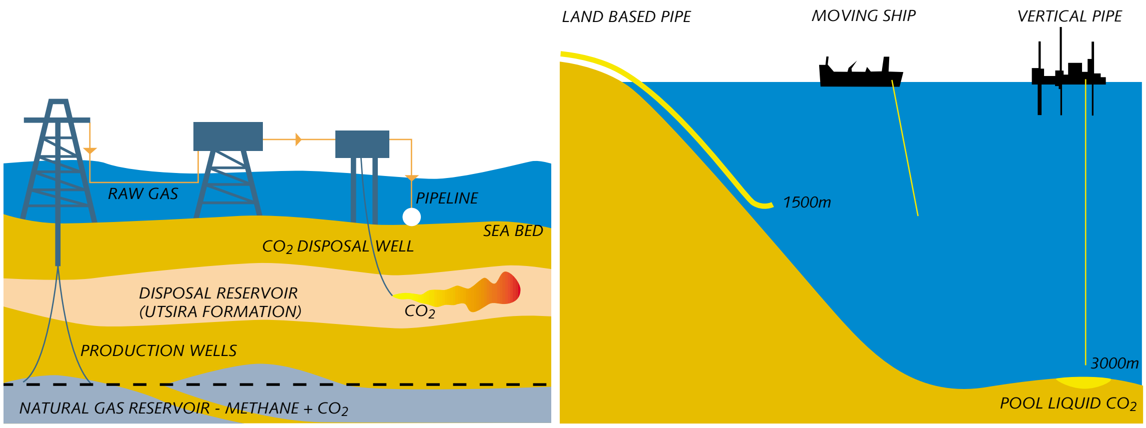


Figure 4: Capturing and sequestering carbon dioxide underground and in the ocean. (CSIRO)

and carbon sequestration

Greenhouse gases released from a source such as the burning of fossil fuels do not stay in the atmosphere forever. There are various processes that remove gases from the atmosphere. These processes are called sinks. A young growing forest, for example, is a carbon sink as the trees absorb carbon dioxide, incorporating the carbon into wood and leaves.

Oceans are both a source and a sink for carbon dioxide, simultaneously releasing and absorbing the gas.

Today, global sources of greenhouse gases are greater than sinks, which is why concentrations of greenhouse gases are rising.

Sequestration involves taking steps to remove gases such as carbon dioxide from the atmosphere. Planting trees is a way of biologically removing carbon dioxide. Alternatively, carbon dioxide released from industry could be collected and pumped into geological formations including oil and gas reservoirs, unmineable coal seams, and into and below the sea.

Biomass as a sink

Forests represent a carbon store. Under ideal conditions, one hectare of new forest can absorb about 25 tonnes of carbon dioxide per year. Trees and other plants are a sink only while they are actually growing. A mature tree, for example, emits as much carbon dioxide through respiration as it absorbs via photosynthesis – a commercial plantation will absorb carbon dioxide for approximately 30 years. Carbon dioxide is also released when vegetation is cleared.

In Australia in 1999, forestry represented a net sink of some 23 million tonnes – equivalent to about 5% of Australia's total net greenhouse gas emissions.

Storage of carbon below the ground

Carbon dioxide can be pumped deep underground and stored in geological formations such as empty gas reservoirs. This approach is being commercially trialed overseas. In Australia, a major investigation of the geological disposal of carbon dioxide has begun. The project, known as GEODISC, will define the most viable locations for injection and help to identify a pilot injection program.

Deep ocean storage

Oceans naturally absorb 20 to 40% of global carbon dioxide emissions.

Australian researchers are studying the potential to collect carbon dioxide gas from power stations and other major sources and pump it directly into the deep ocean.

Another way to increase the rate at which oceans absorb carbon dioxide is to add nutrients. These nutrients stimulate marine biological production, increasing the carbon dioxide absorption rate. The impact on ocean ecosystems would need to be carefully considered before this approach could be used on a large scale.

Figure 4 illustrates forms of geological and oceanic carbon sequestration.

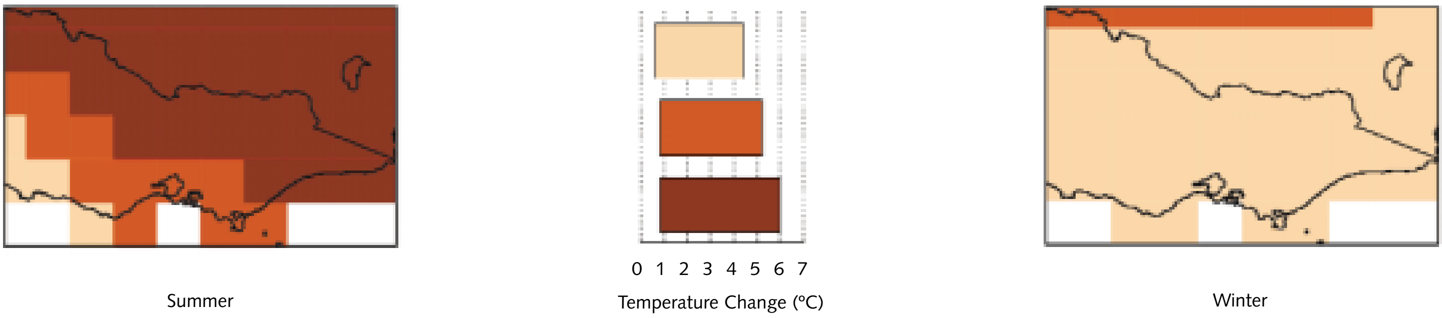
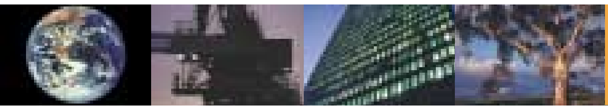


Figure 5: Projected changes in summer and winter average temperatures for the year 2070 relative to 1990. The coloured bars show the range of projected temperature increases for areas with corresponding colours in the maps.



4 Climate change p

By the year 2070 Victoria is likely to be 0.7 to 5.0°C warmer than it was in 1990.

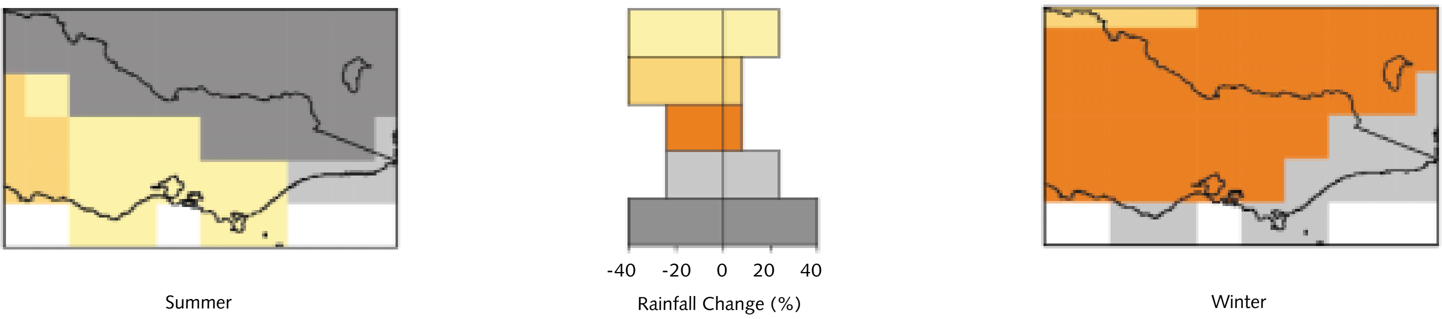


Figure 6: Projected percentage changes in summer and winter rainfall for the year 2070 relative to 1990. The coloured bars show the range of projected rainfall changes for areas with corresponding colours in the maps.

rojections for Victoria

There are many uncertainties associated with estimating how climate change will affect Victoria. We do not know how rapidly greenhouse gas emissions will grow in the decades to come, and there are still uncertainties about some aspects of climate science, such as limitations in our understanding of the climate system.

As a result of all these uncertainties, it is not possible to accurately predict the way in which climate will change in Victoria during the coming decades. Instead, researchers generate projections of climate change which encapsulate a range of possible outcomes. The projections also provide a starting point for studies to assess the regional impacts of climate change.

Projected temperature and rainfall changes in Victoria

Changes in rainfall and temperature patterns, and in the frequency of extreme weather events (e.g. storms), could affect water resources, coastal environments, native flora and fauna, agriculture and forestry. It is important, therefore, that governments and the community have access to the best possible information on likely future climate to help plan for, and adapt to, changed climatic conditions.

The Victorian Government has supported work by CSIRO Atmospheric Research to develop regional climate change projections for Victoria.

CSIRO Atmospheric Research bases its climate change projections on greenhouse gas and sulfate aerosol emissions scenarios prepared by the Intergovernmental Panel on Climate Change (IPCC). This Panel is the international group charged with assessing the latest scientific understanding of climate change.

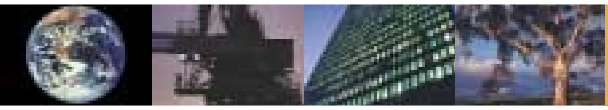
CSIRO's latest projections for Victoria are summarised below and presented pictorially in Figures 5 and 6. These projections allow for key uncertainties such as the range of future greenhouse gas emission scenarios, and the range of results from different climate models – including differences in projections of regional patterns of temperature and rainfall changes.

By the year 2070:

> Victoria is likely to be 0.7 to 5.0°C warmer than it was in 1990
> the frequency of extreme maximum temperatures will increase, with up to 3.5 times more hot days in some areas of the State
> frosts are likely to decrease in frequency, with much of the State likely to become frost-free at the higher levels of projected temperature increases
> rainfall decreases are likely – in most regions, changes in annual rainfall ranging from -25% to +9% are projected
> projected rainfall decreases are strongest in Spring through most of the State, with dry Springs likely to become more common
> extreme daily rainfall events will become more intense and more frequent in many regions
> warmer conditions will lead to increased evaporation which, combined with reduced rainfall, is likely to increase moisture stress.

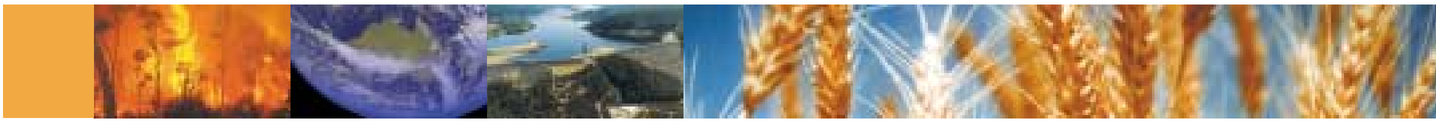
Temperature and rainfall projections for Victoria are periodically updated by CSIRO. Updates will be published on www.greenhouse.vic.gov.au

See also CSIRO's (2001) *Projections of climate change for Australia* which is available at www.dar.csiro.au/res/cm/projections.htm



5 Impacts of climate

Climate change will have potentially major implications for agriculture, water resources, coastal and alpine regions, and human health.



change

Rising atmospheric concentrations of carbon dioxide and other greenhouse gases are likely to lead to global warming and other changes to climate. Globally, average surface temperatures are likely to increase by between 1.4 and 5.8°C over the period 1990 to 2100.

A warmer atmosphere will heat the upper layers of the oceans. Like most substances, water expands when heated. Such expansion will result in higher sea levels. Land-based ice in the temperate regions of the world (such as South and North America and Greenland) will melt more rapidly. Glaciers may retreat.

Scientists estimate that by the end of the 21st century, global warming will raise average sea level by 9 cm to 88 cm compared to 1990. This rise equates to 1 to 8 cm per decade.

Likely Australian changes

CSIRO released new climate change projections for Australia in May 2001. Key elements of these projections are presented below.

Temperature changes

By 2030, it is projected that annual average temperatures will increase by 0.4 to 2°C over most of Australia, with slightly less warming in some coastal areas and Tasmania, and slightly more warming in the north-west.

By 2070, it is projected that annual average temperatures will increase by 1 to 6°C over most of Australia with exceptions similar to those for 2030. Greatest warming occurs in spring and least in winter. In the north-west, most warming occurs in summer.

Rainfall changes

There is a likelihood of rainfall decreases across Victoria in winter and spring. Changes are less certain for the State in summer and autumn.

Most climate models show an increase in extreme daily rainfall due to the enhanced greenhouse effect, leading to more frequent or heavier rainfall events. This can occur even if average rainfall is reduced as a result of climate change.

Tropical cyclones

Predictions of changes to tropical cyclones are difficult because they are relatively small-scale events and are not well resolved by global and regional climate models. However, regions of origin are likely to remain unchanged and intensities may increase by 5 to 20% in some parts of the world by the year 2100.

Future changes in the frequency of tropical cyclones will also be affected by any changes to the El Niño – Southern Oscillation.

Gales and storm surges

Storm surges are mainly caused by tropical cyclones in northern Australia and other severe storms in southern Australia. The number of severe storm surges in the north may increase by the year 2100 as the intensity of tropical cyclones increases. Projected rises in average sea level will exacerbate this effect.

Gales, which are the primary driver for storm surges, are also responsible for large waves contributing to processes such as erosion and sediment transport along the coastline. Gales can be destructive to the natural and built environment. In northern Australia, an increase in the number of extreme gales is likely as tropical cyclone intensity increases.

Ecosystems

Victoria's flora and fauna may face significant change. As well as the impact of temperature and rainfall changes and rising carbon dioxide concentrations, alterations in soil characteristics, changes to water availability and nutrients, and different interactions between species are likely to affect ecosystems.

Changes to runoff, river flow and sea level will affect aquatic ecosystems.

Hydrology and water resources

Higher temperatures are likely to result in an increase in evaporation. Increases in annual potential evaporation range from 0 to 8% per degree of global warming over most of Australia, and up to 12% over the eastern highlands. When projected increases in potential evaporation are considered in combination with projected rainfall change, the result is a decrease in moisture balance on a national basis. Decreases in moisture balance would mean greater moisture stress for Australia.

Alpine regions

Victoria's alpine regions are likely to become warmer and drier in future. There will be higher winter minimum temperatures and fewer days below 0°C. The warmer conditions are likely to substantially raise the snow line.

Agriculture

Carbon dioxide increases are likely to improve the growth of some crops. There will also be the impact of higher temperatures, changed rainfall regimes and soil moisture levels, and possibly increased problems with weeds, pests and diseases.

Higher temperatures are likely to reduce the frequency of frosty days leading to a reduction in years in north-western Victoria suitable for growing fruit that require frosts to assist in its growth. Milk yield is also likely to be lower in warmer conditions.

Coastal zone

Sea level rise and climate change are likely to add to problems with inundation, riverine flooding, saline intrusion, erosion and wave damage. Also expected are impacts of changes in weather conditions, such as winds, waves, storms and storm surges.

Human health

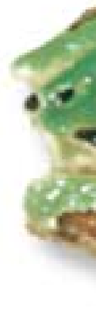
Rising temperatures are likely to lead to an increase in heat stress mortality and urban pollution-related respiratory problems.

Adaptation to climate change

Some level of climate change is inevitable. Preparing for adaptation to climate change is, therefore, an important part of Victoria's greenhouse response.

Development and implementation of adaptation strategies will need to involve all spheres of government, business and the community. It will also need to be based on an assessment of the potential effects of adaptation options, their benefits and costs, the ease with which they can be incorporated into planning processes, and the appropriate timing for their implementation.

Key areas for adaptation strategies include coastal and marine environments, agriculture, biodiversity, forests and human health.



Victoria
The Place To Be